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On the Rings of Saturn. By Professor Secchi.

(*Communicated by the Astronomer Royal.*)

"In an interesting memoir published in the *Proceedings of the Academy of Sciences of St. Petersburg*, vol. v. 6th series, 1852, M. Otto Struve has announced the suspicion that the rings of *Saturn* were in a state of gradual collapse, so that, after a certain interval of time, which probably might not be long, the planet would appear totally deprived of those interesting appendages. The suspicion is the more reasonable, inasmuch as nothing proves that the system is in a condition of permanent equilibrium, and since, not only the early observations, which might be liable to some doubt, but even the most recent observations, support the hypothesis. I extract from the memoir of M. Otto Struve the following table in support of this assertion, which will be found useful hereafter. I add to it the measures of Mr. Lassell for 1853 (*Astronomische Nachrichten*, No. 856):—

Table (A).

Observer.	Epoch.	Exterior Diameter of the Ring.	Diameter of the Planet.
		″	″
Huyghens	1657	45	18
Cassini	1691	45	...
Pound	1719	42	18
Bradley	1719	41·25	17·75
Rochon	1777	40·6	16·9
W. Herschel	1791	46·68	...
W. Struve	1826	40·10	17·99
Bessel	1831	39·30	17·05
Encke	1837	40·93	17·68
Galle	1838	40·90	17·91
O. Struve	1851	39·74	17·61
Lassell	1853	40·88	17·45

"The discordances remarked in these measures are sufficiently sensible, and I have thought that it would not partake of any rashness on my part to attack the question. After having acquired sufficient practice in measures of the planets with *Jupiter*, and having found my measures agreeing with those of M. Struve, I have availed myself of the last opposition and of the maximum opening of the ring, to execute a series of measures, not only of the ring, but also of the planet, so as to ascertain the degree of precision and confidence to which they might be entitled. Each number is the mean of two, and more frequently of three, double measures, which are very accordant, and of which the probable error of an individual measure does not exceed 0″·2. The measures have been executed only under an excellent condition of the atmosphere, except on two occasions, one of which was for the purpose of ascertaining the influence of less favourable circumstances. To the measures made during the last opposition I have

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also added, for the purpose of comparison, those of the opposition of 1854–5. I have not corrected any of the measures for refraction nor for phase,— not that I considered the effects depending upon these causes to be insensible,— but because I perceived discordances of another kind of far greater magnitude, the origin of which I was desirous of examining before I calculated those small corrections.

Table (B).

Days of Observation.	Exterior Diameter of Exterior Ring.	Middle of Principal Division.	Interior Diameter of Ring B.	Interior Edge of Nebulous Ring.	Equatoreal Diameter of Planet.	Transverse Diameter of Ring.
1854.	″					
Nov. 15	40·655	...	...	...	...	...
Dec. 15	41·331	...	...	...	...	...
17	41·008	...	...	...	...	...
1855.						
Jan. 4	40·739	...	...	...	...	...
6	40·733	...	...	...	...	...
Apr. 20	41·205	...	...	...	17·708	...
Nov. 30	40·851	...	23·792	21·232	17·458	18·339
Dec. 5	41·324	34·486	26·101	20·995	17·829	...
14	41·068	...	25·474	...	17·531	20·442
15	41·443	34·657	25·913	21·725	17·773	19·025
16	40·812	34·699	25·834	21·350	17·716	18·504
23	41·118	34·642	25·917	21·605	17·611	18·991
24	40·564	34·760	26·191	21·519	17·687	18·291
27	40·412	...	25·832	21·508	17·572	18·110
	40·623	...	26·003	...	...	...
30	40·710	...	...	...	17·728	...
	41·090	...	26·083	...	...	...
1856.						
Jan. 9	40·483	...	...	...	...	...
Mean	40·893	34·659	25·714	21·419	17·661	18·814

" All the measures have been reduced to the mean distance of *Saturn* from the sun, but the results have not been corrected for the different inclination of the ring on the different days. It will be seen by this table that the discordances in the measures of the ring are very considerable, while, in the case of the planet, they are sufficiently small: for the ring they are generally not less than 0″·5, while the extremes amount to as much as 1″, which is altogether intolerable with this instrument. After spending some time in anxious reflection upon the cause of these anomalous results, I consulted the measures of Mr. Lassell, and in these I found similar discordances. This circumstance induced me to discuss the measures with greater care, and the result has been that I think I have detected a certain period in the irregularities. The measures of two consecutive days do not agree; but those of three days and of nine are consistent. The measures of four days do not agree even in the case of Mr. Lassell's observations. I was

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then led to inquire whether the results might not be explained by supposing the ring to be elliptic, and that by its rotatory motion around its primary, it presented alternately its major and minor axis. Having assumed the period of rotation assigned by Herschel, the results did not combine; but upon trying the period which a satellite would have if it were placed on the margin of the ring, I found, after applying a slight correction, that it satisfied the observations. Let T be the time of rotation of the ring; t, the time which elapses after an observed epoch of maximum; $\varkappa$, the difference of the two axes of the ring; we shall then have the mean diameter = the observed diameter $+ \varkappa \cos 2 \left(\frac{2\pi t}{T}\right)$. If we denote by ω the angle which remains after whole circumferences have been described by the satellite, the correction will be $c = \varkappa \cos 2\omega$,* and it is evident that in a rotation there are two maxima and two minima. The value of T, which satisfies the observations best, is $T = 14^{h}{\cdot}428$ of sidereal time. From the difference between the maxima and the minima I have concluded that $\varkappa = 0''{\cdot}366$, and I have chosen for the epoch of minimum the 24th of December, at $4^{h}\ 10^{m}$ sidereal time, on which occasion the planet was so steady and well defined, that I entertain no doubt respecting the observation. The Table (C) gives the results of these calculations:—

Table (C).

Date and Hour.		Intervals In Time.	Intervals In Revolution.	Correction.	Diameter Observed.	Diameter Corrected.	Deviation from Mean $c - m$.
1855.	h	h m	r o		″	″	
Nov. 30	2·30	24 + 1 40	40½ + 23	+ 0 254	40·851	41·105	+ 0·118
Dec. 5	1·45	19 + 2 35	32 + 76	− 0 323	41·324	41·001	+ 0·014
14	3·00	10 + 1 40	17 + 24	+ 0 245	41·068	41·311	+ 0·227
15	3·30	9 + 0 40	15 + 81	− 0 348	41·443	41·095	+ 0·108
16	3·30	8 + 0 40	13½ + 12	+ 0 334	40·812	41·146	+ 0·159
23	4·10	1 + 0 0	1½ + 65	− 0 235	41·118	40·883	− 0·104
24	4·10	...	...	+ 0 366	40·564	40·930	− 0·057
27	3·40	3 − 0 20	5 + 12	+ 0 334	40·412	40·746	− 0·241
,,	4·10	3 0 0	5 + 20	+ 0 280	40·623	40·903	− 0·084
30	3·50	6 − 0 20	10 + 32	+ 0 160	40·710	40·870	− 0·117
,,	4·20	6 + 0 10	10 + 45	0 000	41·090	41·090	+ 0·108
1856.							
Jan. 9	5·28	16 + 1 18	27½ + 20	+ 0 280	40·483	40·763	− 0·224
					Mean ..	40·987	

"The column of corrected diameters presents a satisfactory agreement throughout a period, including forty revolutions of the ring. The outstanding differences are sufficiently small and of the order of the errors of observation, although there is a tendency to a positive excess in the earlier part. The correction for refraction was not, indeed, applied; and as the hour-angle frequently amounted to between 2^{h} and 3^{h}, some hundredths of a second might be gained

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* The powers of the excentricity, which are higher than the second, are not taken into account.

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in this way, but this would not suffice to make the differences altogether vanish. On the contrary, the excess observable may have the same origin as the anomalies which have characterised the measures of the celebrated astronomers who have formerly devoted their attention to this subject, that is to say, they may arise from real variations of the ring. It will be seen by the above measures that the means of the results of Tables (B) and (C) are not very different from those obtained by MM. Encke, Galle, and Lassell, but deviate from those of MM. W. Struve, Bessel, and Otto Struve, to an extent which far surpasses the probable limit of the errors of observation. It will then be desirable, in order to detect these variations, to compare the breadth of the actual rings with that which has been assigned by M. W. Struve. The mean obtained by M. Otto Struve (memoir above cited) from the observations of MM. W. Struve and Encke and those executed by himself is the following:—breadth of the exterior ring = 2″·440. From our measures we have determined the breadth of the ring to be 2″·911, taking into account the breadth of the division which has been found = 0″·402; the difference, therefore, amounts to 0″·475 (*a*).* On the 29th of December I was struck with the excessive apparent breadth of the exterior ring, which appeared to the eye broader than in the incomparable drawings of Lassell, Dawes, Otto Struve, and others. I was induced, therefore, to have recourse to actual measurement, and I found the total breadth from the

Exterior Border of A to the Interior Border of B to be = 7″·512
Also Breadth of A ... ... = 2·788
According to Struve ... . = 2·440
Difference ... 0·348

"The difference is sufficiently great to confirm what simple inspection had already led me to suspect.

"On the 27th of December the state of the atmosphere was very favourable. The two ansæ of the rings were measured. For the preceding ansa we found,—

	r	Reduced Breadth.
Double Breadth, including the wires =	1·178	
— — — —	1·178	8″·6055
— — — —	1·177	

(Revolution of the Screw = 15″·4667)

"For the following ansa,—

	r	Reduced Breadth.
— — — —	1·196	
— — — —	1·197	8″·7506
— — — —	1·197	
According to Otto Struve		7″·15

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* The third column in Table (B) gives the diameter of the middle of this division (*a*), upon which the middle of the wire was placed.

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"The agreement of the individual measures would not justify us in attributing the difference to errors of observation; but without having recourse to any exaggeration, it may be seen that the ansæ are somewhat unequal, and that the breadth of the rings was greater than usual. From the above measures (Table B) it results that the interior diameter of the exterior ring A = 35″·061; W. Struve makes it = 35″·289; the difference is 0″·228; a quantity which is tolerable, but cannot be neglected in an object like this, which admits of being seen with such precision and facility, under a favourable condition of the atmosphere. It would follow, therefore, that the division has only in a slight degree shifted its position. If, then, there exists any variation, it must be in the breadth of the exterior ring. The ratio of the breadths of the two rings ought, consequently, to vary; and this circumstance might explain the discordance between the indications of Cassini and succeeding astronomers, in regard to the value of that ratio. In like manner the ratio of the dark space between the ring and the planet to the breadth of the ring ought to vary. The ratio of the former of these two quantities to the latter is,—

According to Otto Struve	0·49
Encke and Galle	0·57
W. Struve	0·64
Bradley	0·95
According to my last measures ...	0·53

"We should, then, be disposed to conclude that this system is subject to sensible variations. I should have wished, for this purpose, to wait for new observations; but I have thought that I ought no longer to delay communicating these results to astronomers, in the hope of engaging them to take exact measures of the ring while the opening has attained its maximum value; for it is to be feared that when the ellipse becomes more acute at the summit, the difficulties will become greater, and the results will be diminished. I offer the foregoing views merely as an essay which future observations may confirm or refute. It will be important henceforward to note exactly the time of observation and to indicate it along with the results obtained. The want of this indication has prevented me from profiting by several interesting observations. The practice of noting the time simply in so far as it is necessary for ascertaining the correction for refraction, is no longer sufficient.

"I shall conclude this paper by extracting from my Journal some observations relative to the appearance of the planet:—

"*24th December.* Atmosphere magnificent; charming image; the exterior ring A exhibits two well-defined streaks, and is, as it were, divided into three rings. The distance of the principal streak from the interior border of A being measured, was found equal to 1″·596. The second streak is very fine, and is distant

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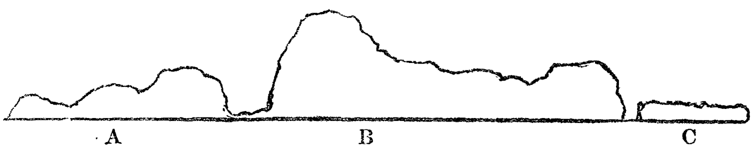
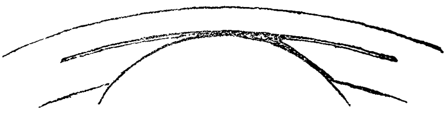
from the interior border of A at the utmost, 0″·5. These two streaks are seen not only at the ansæ, but all round the perimeter, except above the planet, where they are somewhat confused. The principal division *is not black*, but of the colour of the nebulous ring, C, that is to say, somewhat reddish. On other occasions it appeared bluish, indicating thereby changes of colour. The division is very nearly, but not quite so broad at the ansæ, as the wire of the micrometer (that is to say, nearly 0″·402). The difference of colour may be distinguished very well from the contrast of the two small points of black shadow which are seen on both sides of the summit of the planet, and of which one is broader than the other. The pole of the planet almost touches the ring A by a veritable mathematical contact. The ring B is seen with its light graduated, and somewhat brighter towards the interior edge. The curve here exhibited gives the approximate degree of the intensity of the light of the rings. The division between B and C is seen well defined; its breadth equal to half the principal division. The ball of the planet presents a very brilliant band. Upon carefully examining the curvature of the lower margin of this band, we see that *it has not exactly the continuation of the nebulous ring;* so that the latter traverses the planet in a different part, and is projected beneath the bright band, and upon a more obscure zone. The pole of the planet is greenish grey, magnifying powers, 1000 and 500.



"*27th December.* The nebulous ring very well defined: more bluish than usual. *Enceladus* is very well seen in the field without making the planet go out of it. It is recognised by means of the position which it occupied in the preceding day. The globe scarcely touches the ring A; magnifying power, 1000 and 700. The principal division *is not black.*

"*31st December.* The globe exhibits a very small black filament under the border of A. This is verified by M. Galli (this young man has an excellent sight; he sees habitually, besides the seven stars of the *Pleiades*, three others the positions of which I have verified by means of the map). However, it is far from being under all the division. I would value this zone at one-eighth of a second. The shadow laterally is sufficiently developed, but it presents a protuberance at the summit (see the annexed figure). The nebulous ring well defined, but it traverses the planet in a part different from the inferior limit of the bright zone. (Upon observing at a distance with the telescope a



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globe of crystal, in which is contained a jet of illuminating gas: the tinge of the crystal resembles that of the nebulous ring.)

"11*th January*, 1856. The two ansæ of the ring C are of different shades. This, on the side of the shadow, is blue; the other, reddish. The eye-pieces are achromatic, and have been changed expressly for that purpose."

On a new Variable Star. By J. R. Hind, Esq.

"On the evening of December 15th, 1855, I remarked in R.A. (1856) $7^h\ 46^m\ 33^s{\cdot}65$, N.P.D. $67^\circ\ 37'\ 17''{\cdot}1$, an object shining as a star of the ninth magnitude, with a very blue planetary light, which I have never seen before during the five years that my attention has been directed to this quarter of the heavens. On the next fine night, Dec. 18, it was certainly fainter than on the 15th by half a magnitude or more. Since that date I have not had an opportunity of examining it till last evening, January 10th, when its brightness was not greater than that of stars of the twelfth magnitude. It is evidently a variable star of a very interesting description, inasmuch as the minimum brightness appears to extend over a great part of the whole period, contrary to what happens with *Algol* and *S Cancri*.

"The position given above was deduced by micrometrical comparisons with the principal component of the double star Σ 1158. The *variable* precedes $1^m\ 26^s{\cdot}53$, and is N. $7'\ 30''{\cdot}8$.

"*Mr. Bishop's Observatory*, 1856, *January* 11."

On the Occultations of the Star Antares (α Scorpii) in the Year 1856. By G. B. Airy, Esq., Astronomer Royal.

"In the year 1856 there will be several occultations of *Antares* by the moon visible in England, namely, on March 26, June 16, and August 10.

"It appears desirable that advantage should be taken of these phenomena for observation of the double character of the star.

"*Antares* is the only close double star of the first magnitude. Its duplicity was discovered, so far as I am aware, by Professor Mitchell, of Cincinnati, on the 13th of June, 1846,* with the large Munich telescope, mounted equatoreally in the Observatory there.

"After the double character of the star had been discovered by direct observation, it was remembered that, in the accounts of observed occultations of *Antares* by the moon, it had been remarked that the light of the star did not disappear or reappear entirely at one instant, but at two instants, with such a sudden change or *saltus* in the character of the light as made it probable that the small companion was seen for a time, while the large star was hidden by the moon.

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* Silliman's *American Journal* (New Series), vol. i. p. 315.